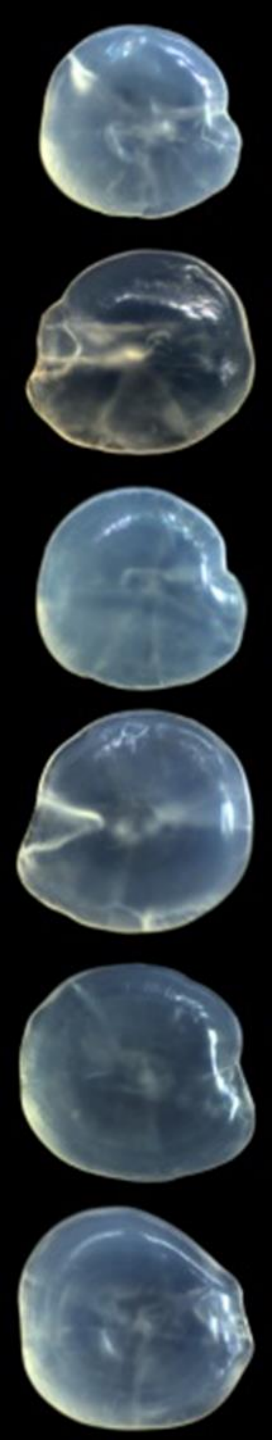


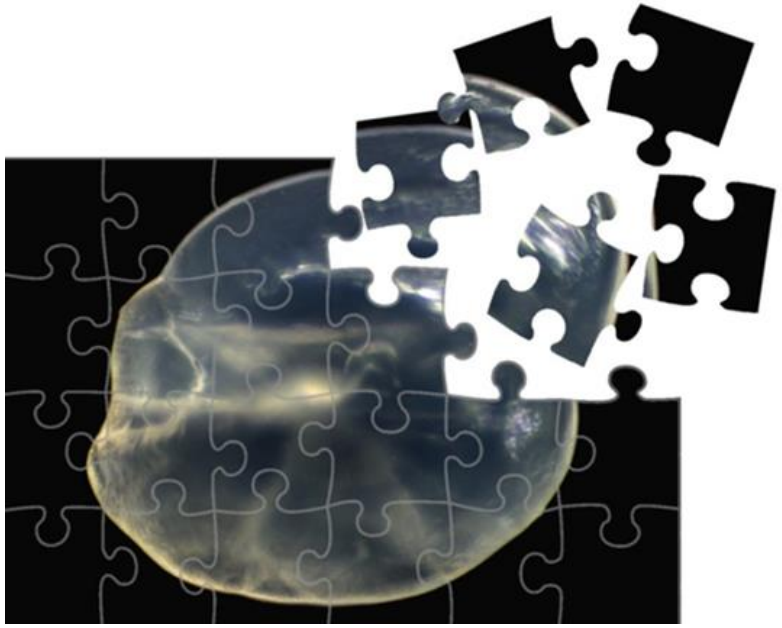
Shapes and landscapes- a morphological approach to the meta-population dynamics of a galaxiid

Eimear Egan

Mike Hickford

John Quinn

David Schiel



UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

MARINE ECOLOGY RESEARCH GROUP
UNIVERSITY OF CANTERBURY, NZ

NIWA
Taihoro Nukurangi

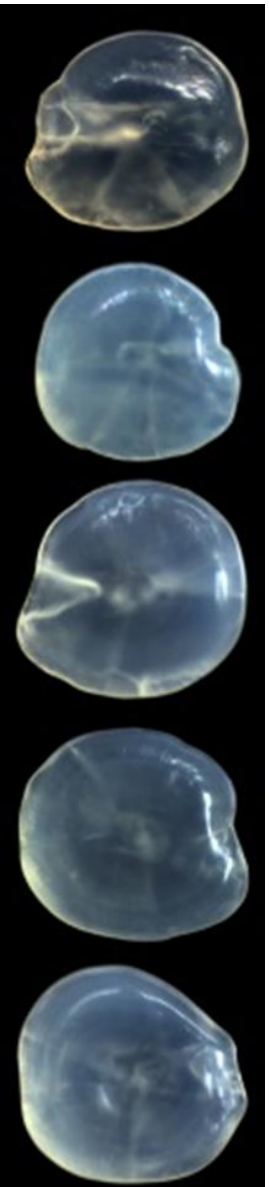
Marine dispersal in Inanga; where do they go and what do they do?

- Amphidromous
- Larval black box
- Whitebait fishery
- Conservation status

- declining

Early life history reconstruction-
Otolith morphology

How to describe otolith morphology?

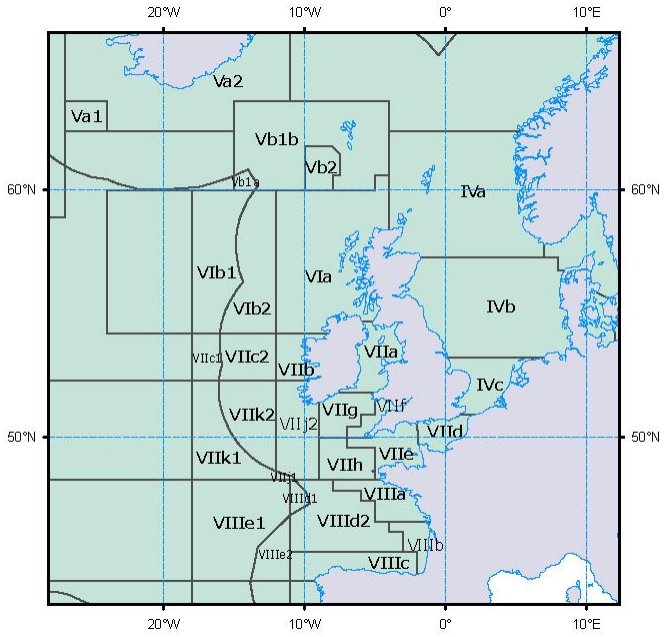


1. Traditional descriptors
   - Area, perimeter, length, width
   - Roundness, rectangularity, ellipticity

2. Elliptical Fourier analysis
   - Outline technique, Ptolemy's ellipses
   - Each harmonic= 4 coefficients (a,b,c,d)
   - Low numbers describe gross morphology and higher numbers describe localised changes

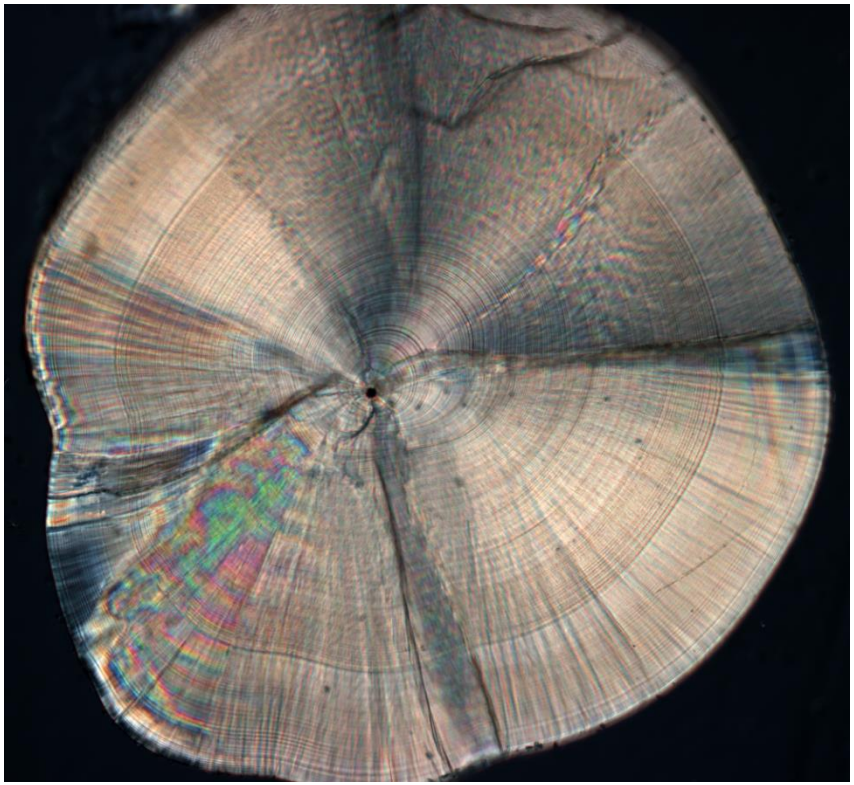
Applications of otolith shape

- Diet and foraging behaviour
- Cryptic species discrimination
- Characterising aggregations at spawning & foraging grounds
- Species identification fossil records

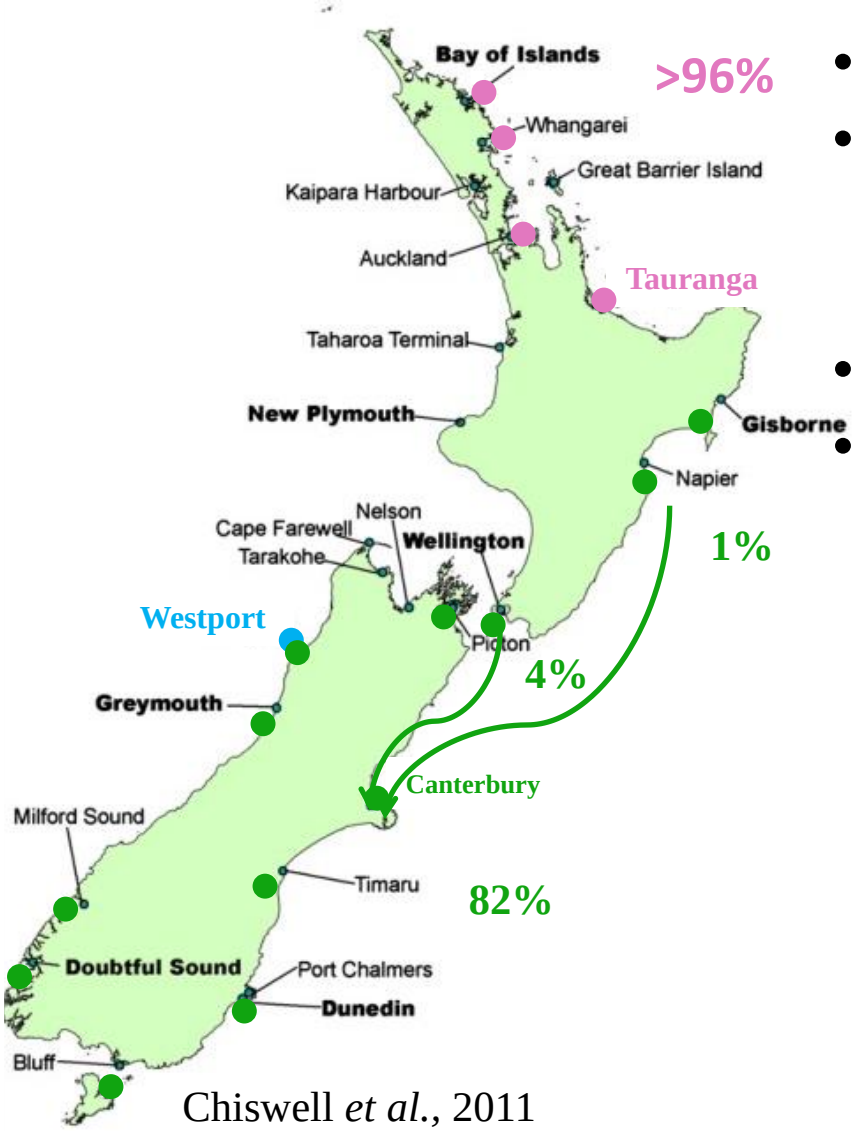


What influences otolith morphology?

- Genetics
- Environment (food, temperature)
- Genetics* Environment
- Growth history
  - Embryonic development
  - Exogenous feeding
  - Metamorphosis
  - Recruitment

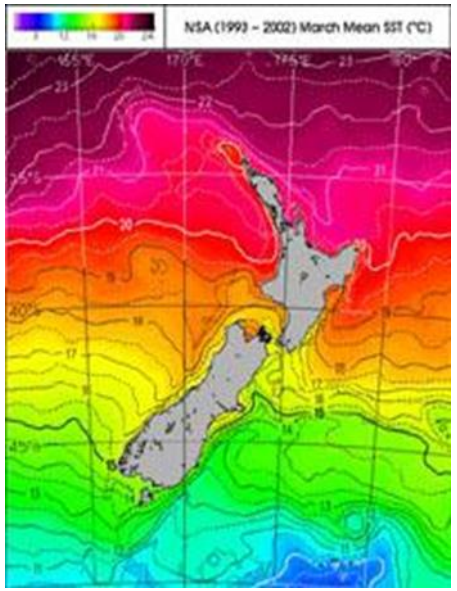


Connectivity over large geographic scales

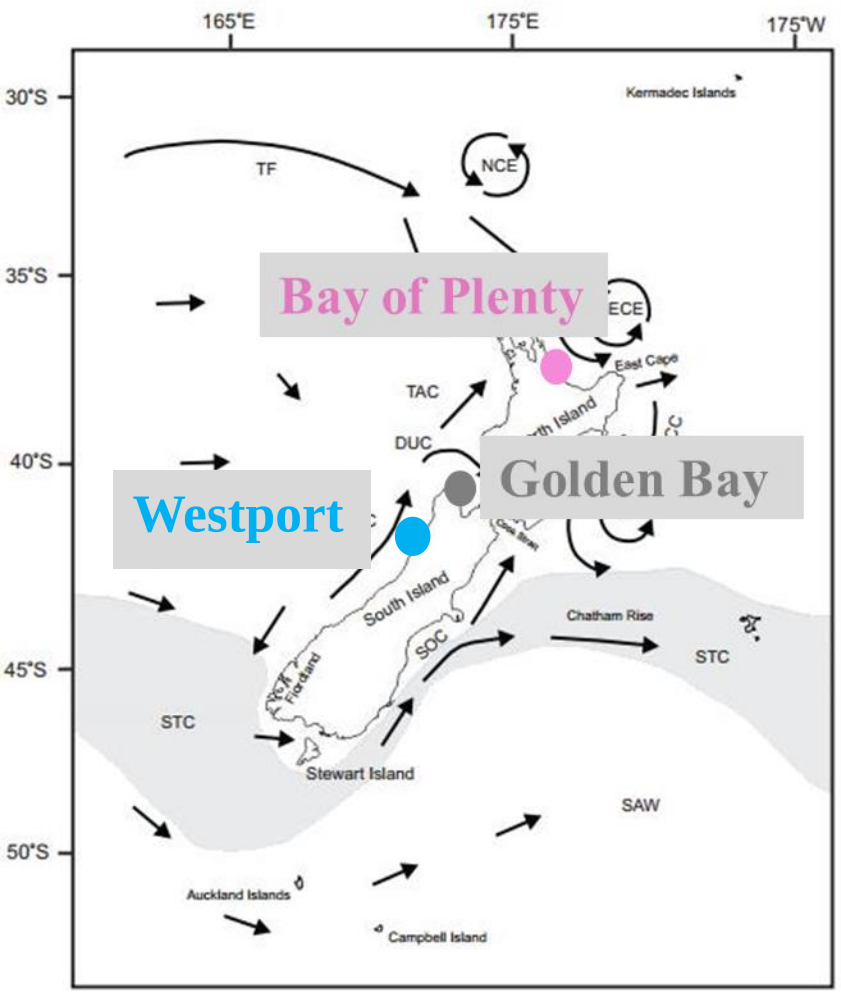


Chiswell *et al.*, 2011

- Panmictic
- Propagule modelling, exchange between West coast of South Island and Bay of Plenty unlikely
- Dispersal pathways
- PLD decreases with increasing temperature



Connectivity over large geographic scales



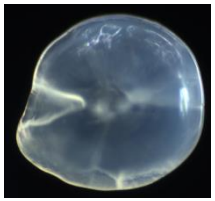
- Key question:

Does otolith morphology differ between populations?

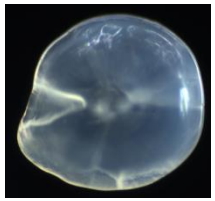
Sampling

- Inanga “whitebait” sampled from 3 rivers in 3 regions at freshwater migration
- Oceanographic information and environmental conditions
- Sep ‘13 cohort

Methods



- 100x mag



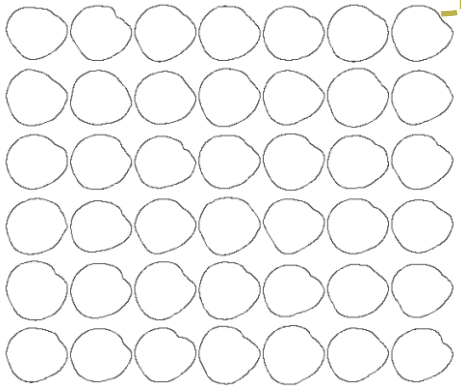
- Area
- Perimeter
- Length
- Width

Aspect ratio
Form factor
Circularity
Ellipticity
Roundness
Rectangularity

Shape indices

- Outline coordinates (x,y)
- Fourier analysis (Momocs in R)

1. Standardise outline
(removes size effects)
   - Centred
   - Scaled
   - Aligned



2. Harmonic power → 40 variables
need to accurately describe otolith outline

Elliptical Fourier coefficients

Data analysis

Shape indices

- ANCOVA (homogeneity of slopes, fish length covariate)
- Size standardisation

(Si_c= Shape indices-slope* fish length)

- N= 5 variables
- Univariate ANOVA
- Principal components (correlation matrix)

Ellipitical Fourier harmonics

- Size standardisation (otolith centroid size)
- N= 36 variables
- Univariate ANOVA
- Principal components (covariance matrix)

- Linear discriminant analysis (ordinate groups)
- Jack-knife reclassification

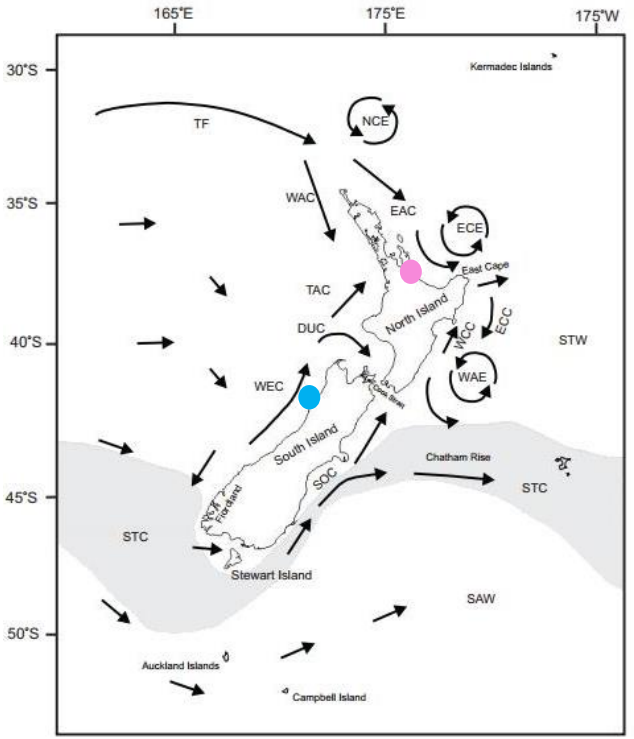
Results

ANOVAS:

Shape indices ----------> Form factor, **Bay of Plenty** and **Buller**

Elliptical Fourier harmonics ----------> C7,D3,D5 and D8

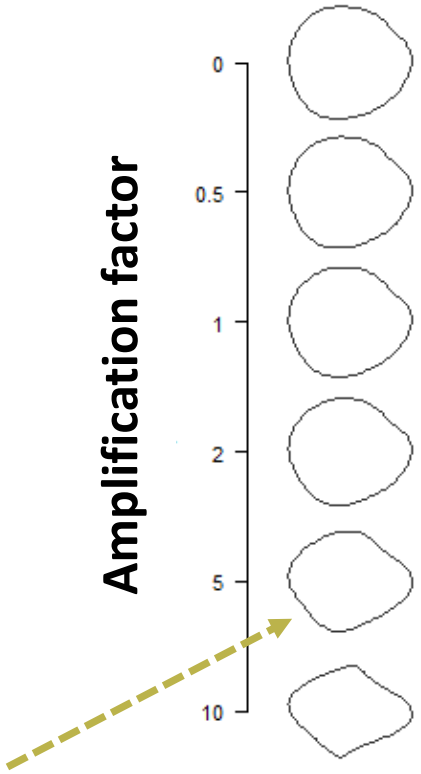
Bay of Plenty and **Buller**



There are differences in otolith morphology

Elliptical Fourier harmonics ----------> C7,D3,D5 and D8

Bay of Plenty and **Buller**

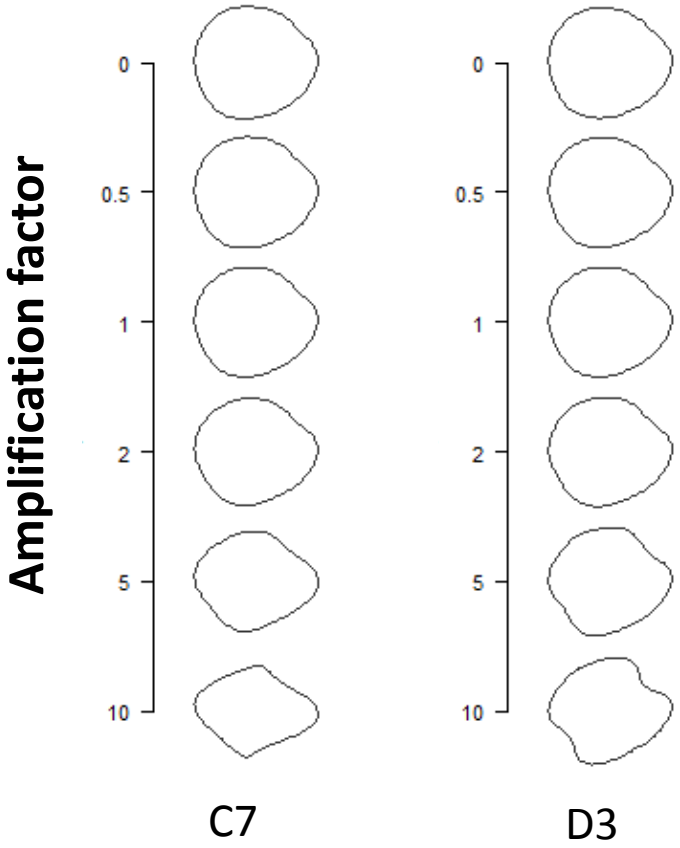


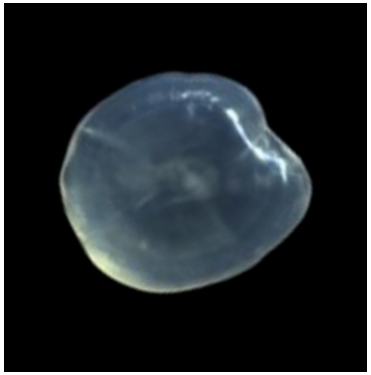
"Kite shaped"

There are differences in otolith morphology

Elliptical Fourier harmonics ----------> C7,D3,D5 and D8

Bay of Plenty and Buller

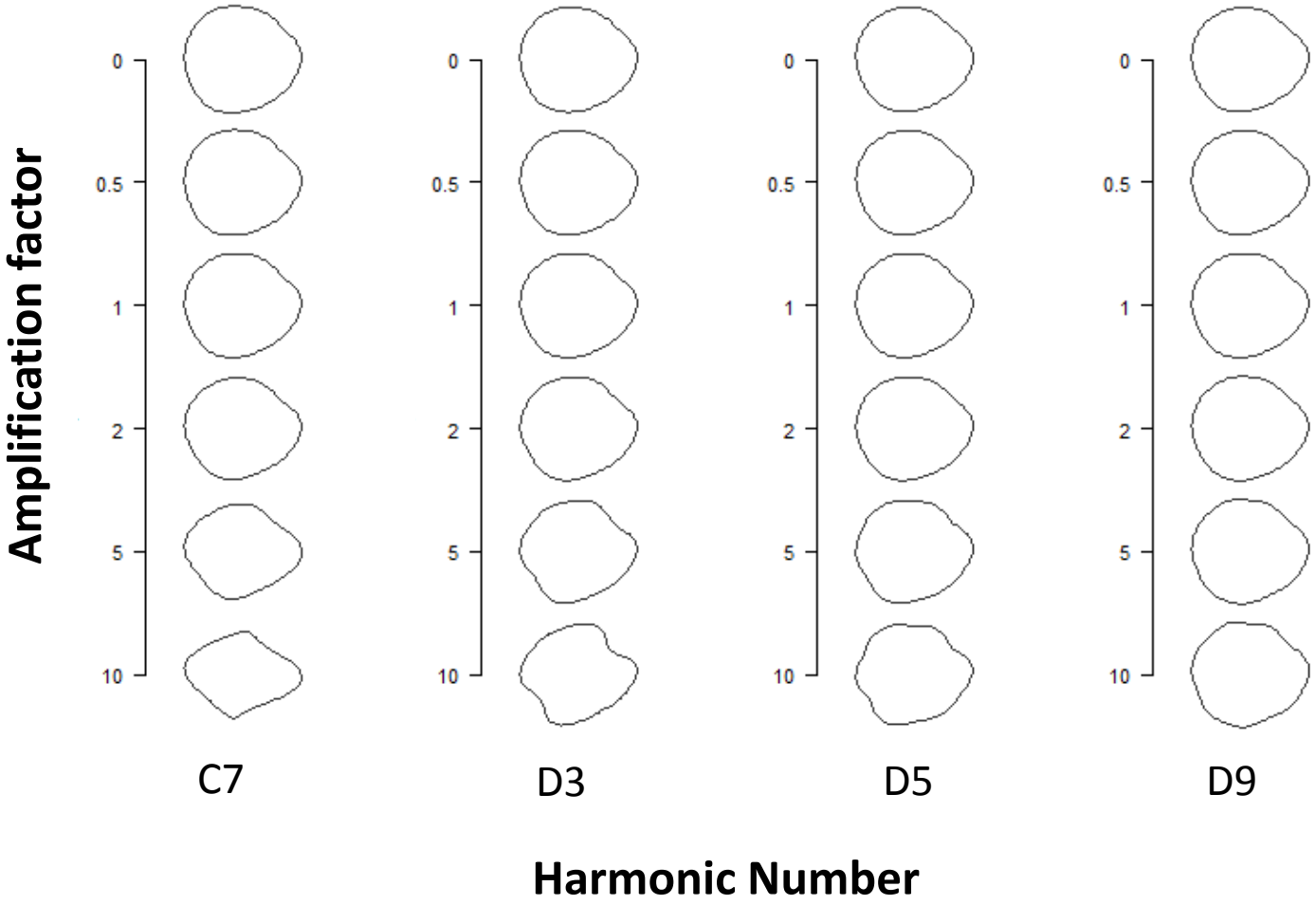




There are differences in otolith morphology

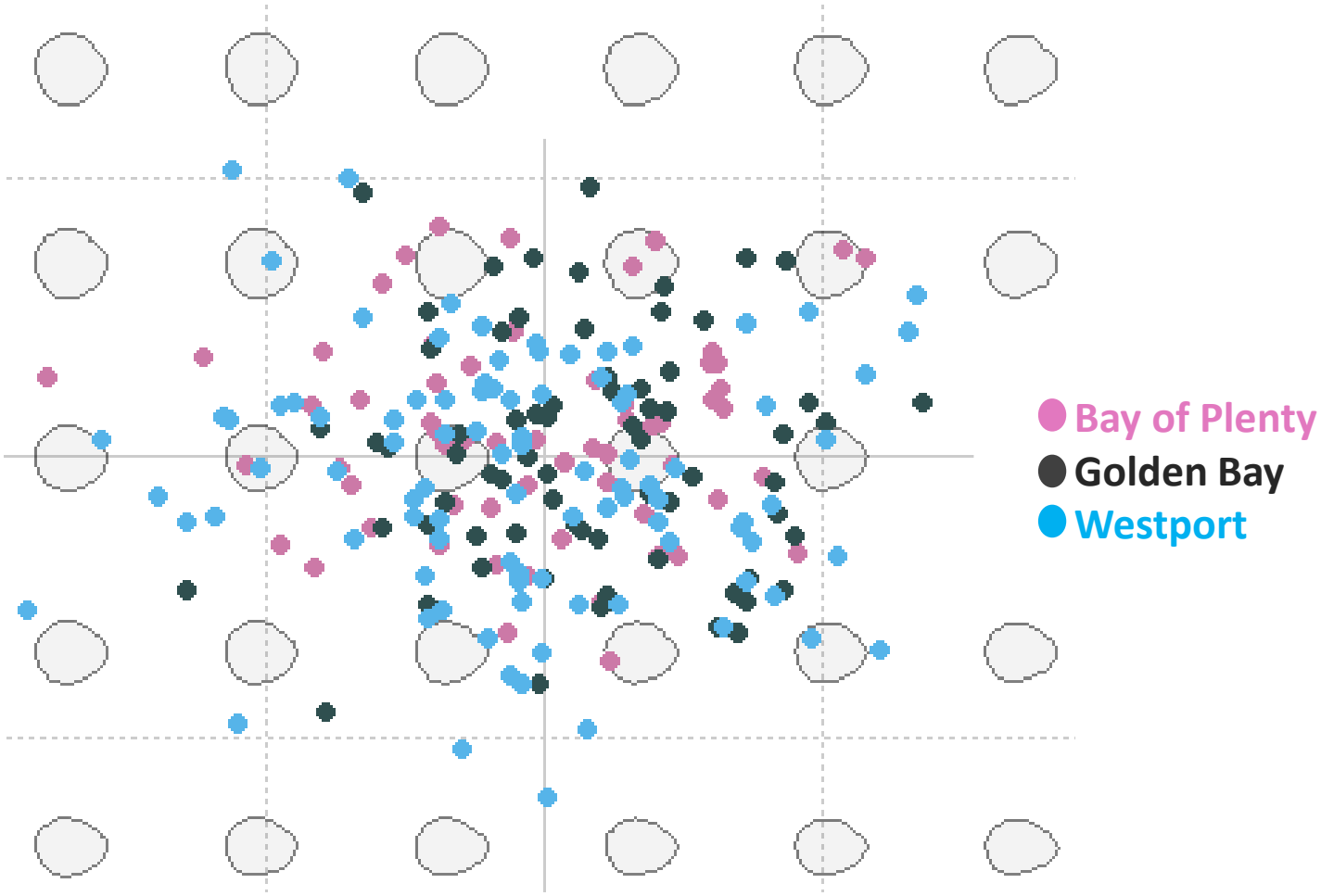
Elliptical Fourier harmonics ----------> C7,D3,D5 and D8

Bay of Plenty and Buller

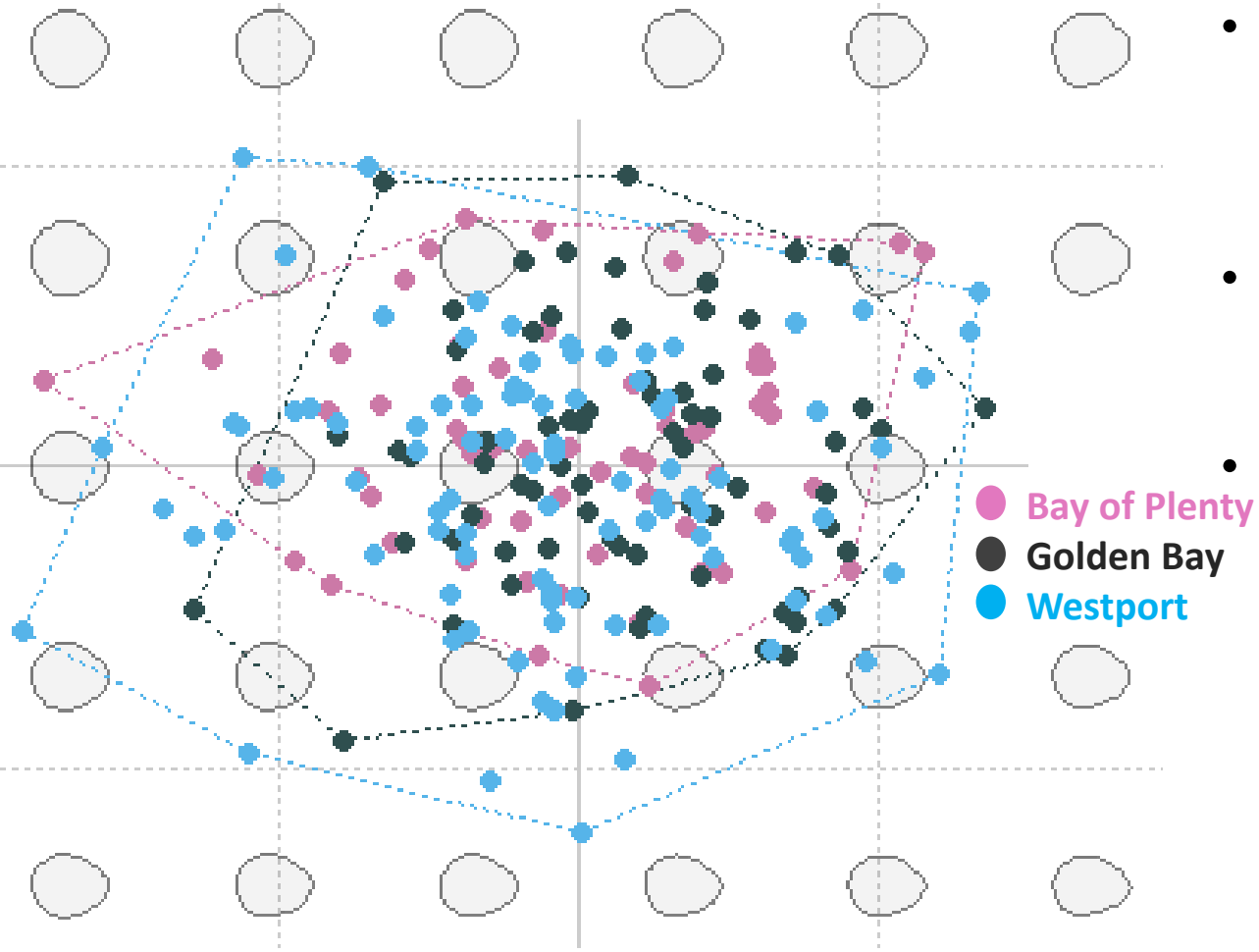


Otolith shape is highly variable

- Reconstruction of individual otolith outlines with Fourier analysis - Morphospace



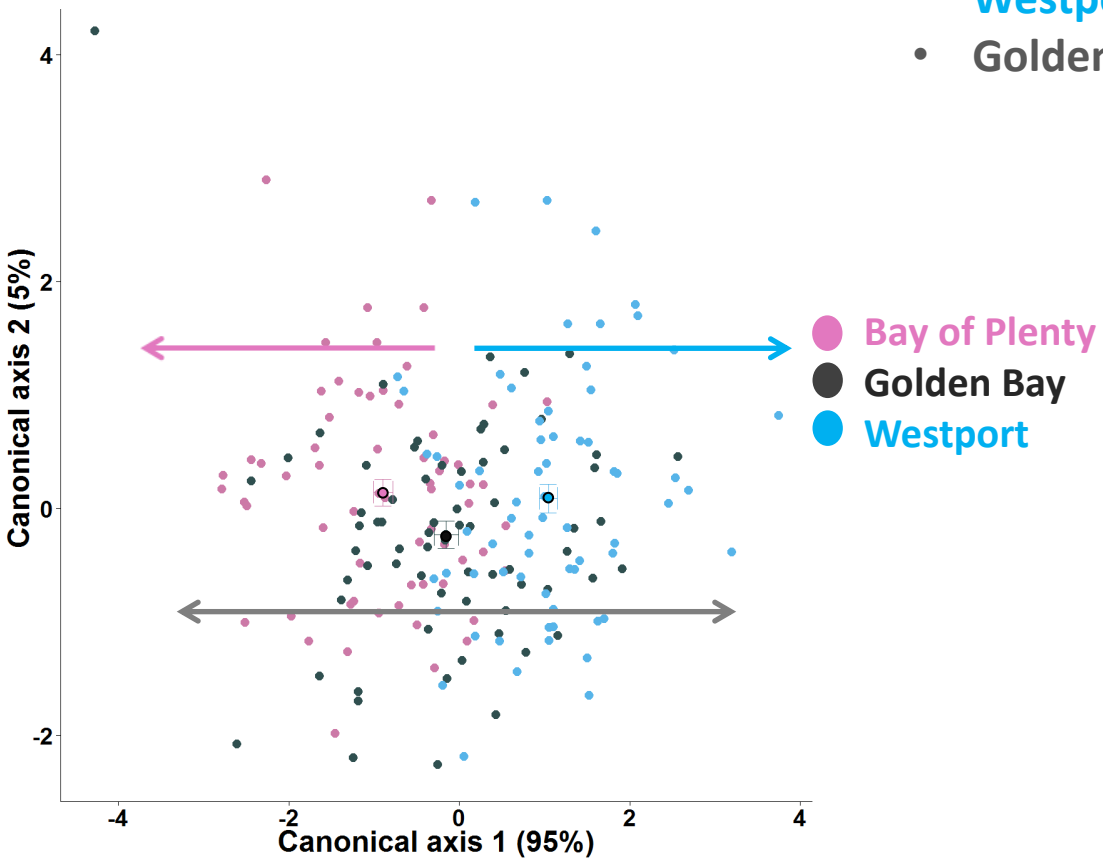
Otolith shape is highly variable



- 7 PCS of Fourier harmonics dataset
  = 95% variance
- 3 PCs of shape indices = 95%
- No obvious grouping

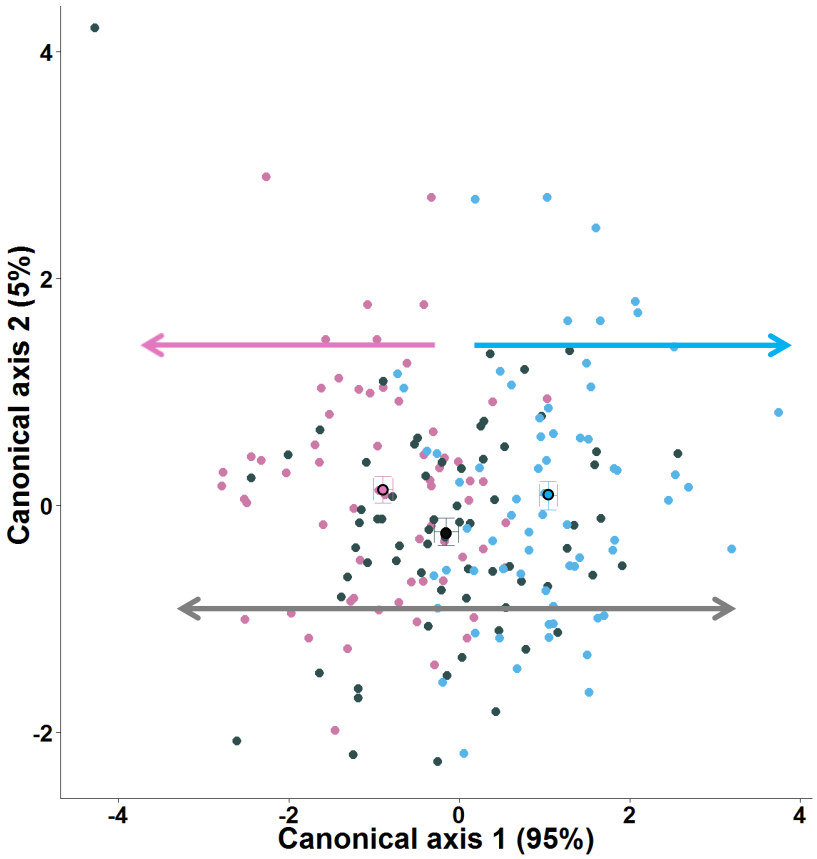
Can otolith shape reclassify fish back to their hypothetical population?

- Significant differences **Bay of Plenty** & **Westport**
- **Golden Bay** high overlap, no discrimination



1st Canonical axis , χ^2, p<0.0001

Can otolith shape reclassify fish back to their hypothetical population?



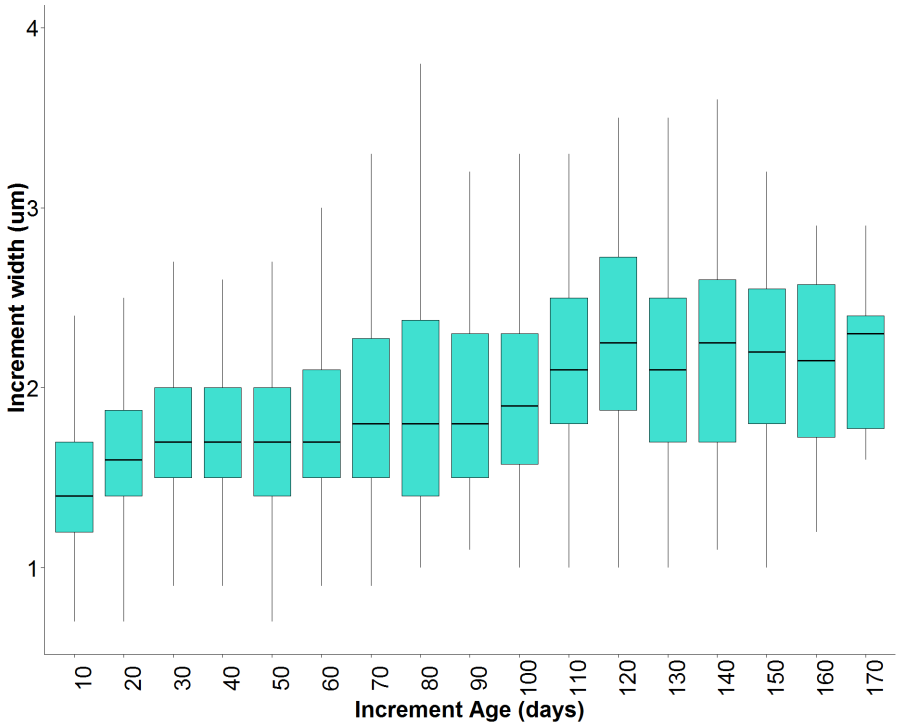
1st Canonical axis , χ^2, p<0.0001

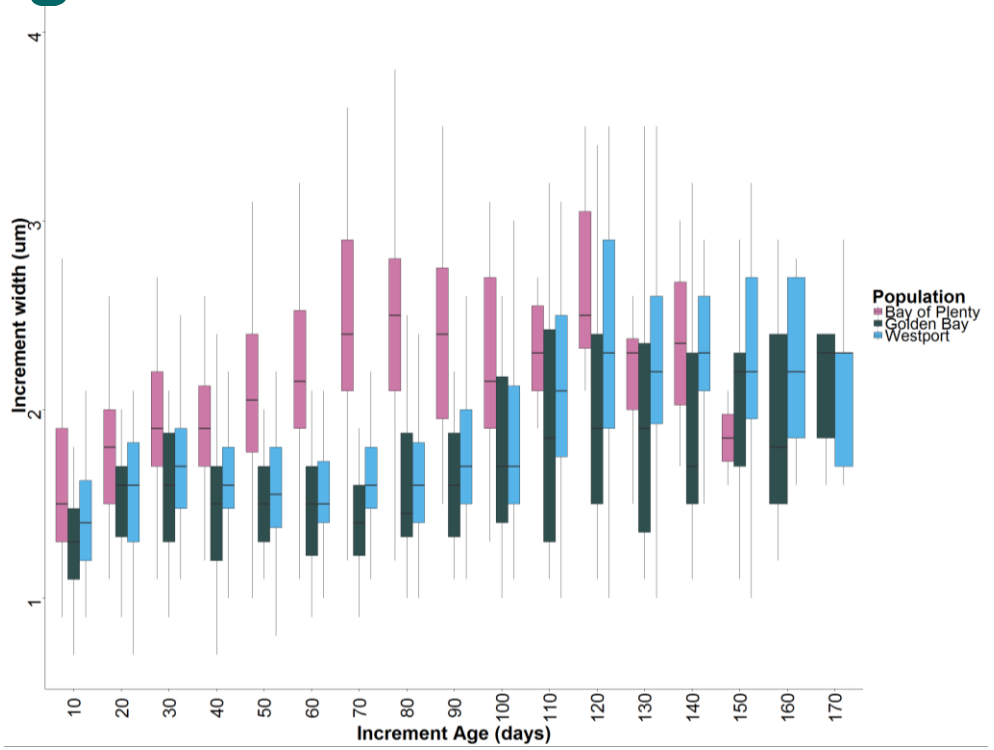
- Significant differences Bay of Plenty & Westport
- Golden Bay high overlap, no discrimination

Population	Classification success %
Bay of Plenty	57%
Golden Bay	32%
Westport	74%

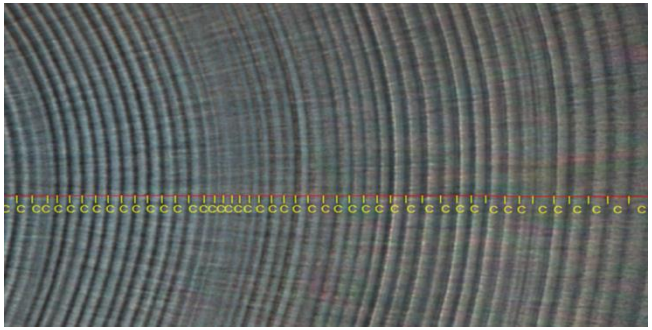
- Westport considered a single population
- Golden Bay and Bay of Plenty, zones of greater mixing /mixed populations

Geographic differences in growth contribute to otolith morphological differences





- Allometric increase in growth with age



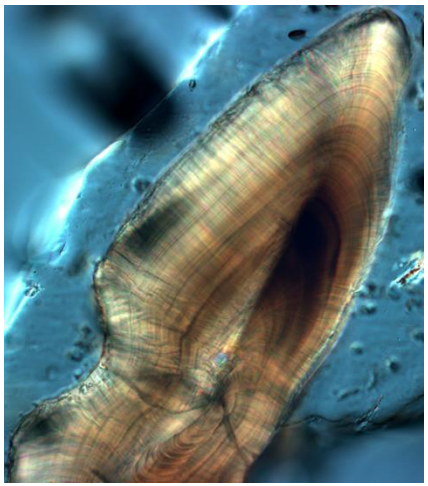
- Similar trend of increased growth with age
- But Bay of Plenty – higher age dependent growth than southerly populations
- Mixed models – Population and population*age, p<.000

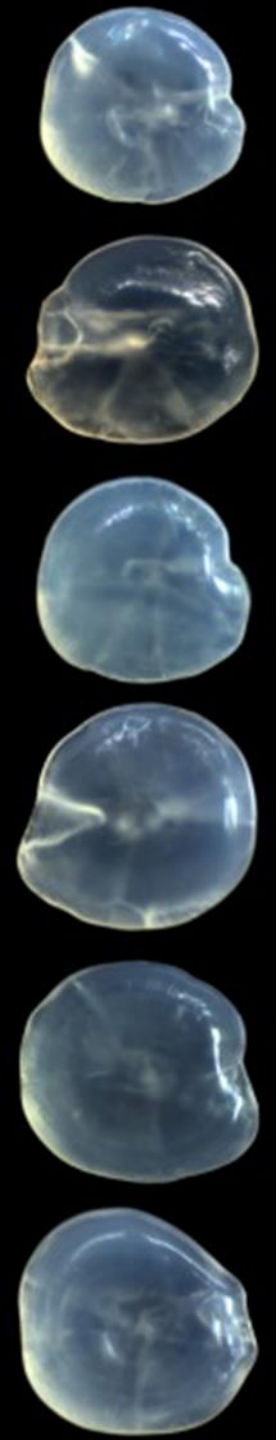
Consequences for meta-population dynamics?

Chiswell *et al.*, 2011

- Consistent with oceanographic patterns
- Greater diversity of phenotypes entering Golden Bay and Bay of Plenty
- Onshore vs offshore development?
- Otolith microchemistry – dispersal and local recruitment (Hickford *et al.,* 2015)

- Complement shape results with microchemistry
- Life histories in adult freshwater environments





Acknowledgements

- **Research**
  - Ministry of Business, Innovation and Employment (C01X1002)
  - National Institute of Water and Atmosphere
- **Fieldwork**
  - University of Waikato Coastal Marine team
- **Laboratory work**
  - Jan McKenzie for assistance with microscopy

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

MARINE ECOLOGY RESEARCH GROUP
UNIVERSITY OF CANTERBURY, NZ

NIWA
Taihoro Nukurangi

NEW ZEALAND MARINE SCIENCES SOCIETY
TE HUNGA MĀTAI MOANA O AOTEAROA

Otolith shape is highly diverse